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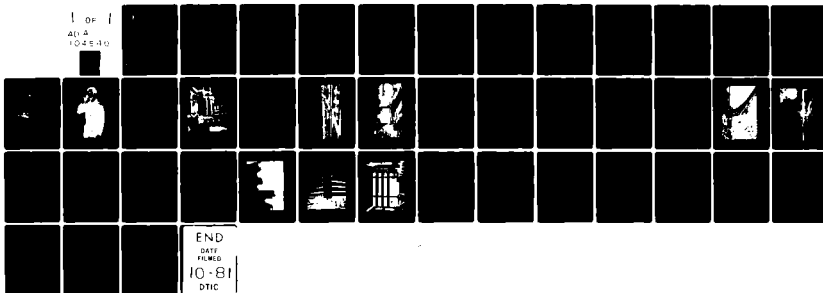
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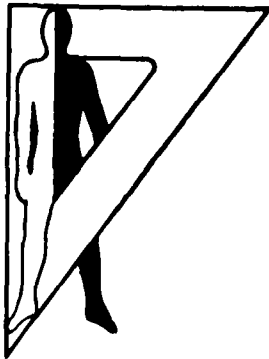
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COMMUNICATIONS TESTS WITH TACTICAL RADIOS
IN A LARGE URBAN AREA

Ellsworth B. Shank
Walter N. McJilton
William C. Mullen

July 1981

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All communications attempts were with the operators at street level or at various floor levels inside of buildings.

The results of these tests do not preclude use of the PRC-77 and PRC-68 radios in military operations in built-up areas.

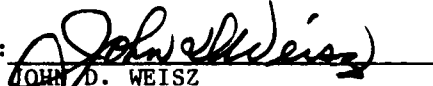
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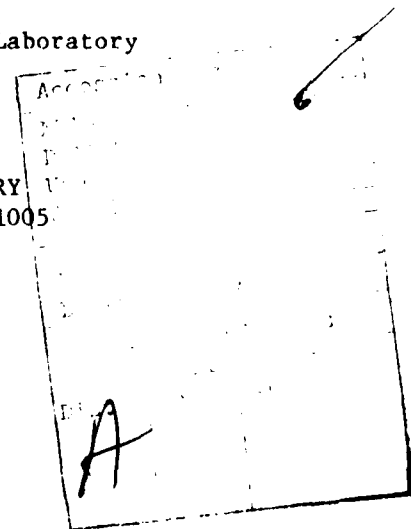
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SUMMARY

The AN/PRC-77 and AN/PRC-68 radios provided adequate signal-to-noise ratios as judged by the participants, such that communications could be accomplished in built up areas under the tactical conditions investigated; although speech intelligibility was not tested.

Street-to-Street Tests

Although the reliable communications ranges decrease as the built-up area becomes more densely filled with structures, the Army's FM 90-10 calls for reduced sectors of responsibility as the built-up area becomes more dense and there appears to be a reasonable matching of radio range performance and the range size of unit sector of responsibility as the density of the built-up area changes.

Some change in range performance was observed in these tests as frequency was varied from 30 MHz to 70 MHz. In particular, the low band performance (30 MHz) was best in the open areas and poorest in the densest built-up area.

Building-to-Building Communications

There are two counter-balancing factors which apparently influence performance. As expected, being inside a building causes some attenuation of the propagated radio frequency energy, but as the operator moves higher in the building conditions are improved. The building-to-building tests were limited in scope, but it should be emphasized that the basic ability to communicate under certain circumstances was evident. Both the building-to-building tests and the building-to-street tests indicate that favorable conditions exist between an operator in a building or the street and an operator relatively high (three to four stories) in a building. Furthermore, two operators who are located about three stories or higher inside buildings can readily communicate with each other over distances of 1 kilometer.

Building-to-Street Communications

For the specific condition of these tests, communications between an operator on the third floor inside a building and a man on the street was an improvement over two different positions on the street. However, the communications between an operator in a building on the second floor and a man in the street showed no appreciable difference from two operators at street level.

Although the results from these particular tests did not directly confirm the limitation, it is evident from other tests that relatively low power radios, such as the PRC-77, cannot be expected to provide a complete

netting of units without special augmentation. For example, two command posts (CPs) located inside buildings at the ground level or lower could not expect to communicate with each other unless the CPs were nearly co-located.

Future tests will be required to determine whether or not available retransmission equipment, remote antennas or other remoting equipment can provide a complete netting of tactical radios under MOBA conditions. These tests are planned for the spring of 1981.

COMMUNICATIONS TESTS WITH TACTICAL RADIOS

IN A LARGE URBAN AREA

BACKGROUND

Investigations of the capability of the PRC-77 and other communications equipment in Military Operations in Built-Up Areas (MOBA) was initiated by the US Army Human Engineering Laboratory (USAHEL) as part of their MOBA Lead Laboratory responsibility after a search of the literature provided little basic data on actual performance for low power transceivers in built-up areas. At the time these tests were conducted, we were unable to locate any performance data on the use of the PRC-77 or other similar Army equipment in built-up areas.

The earlier studies by Advanced Research Projects Agency contractors (4) using limited field data and specifying relatively demanding scenarios indicated that communications in built-up areas would be extremely difficult. On the other hand, field reports of actual operations during the Vietnam war in Hue, during the military activity in Beirut, Lebanon (3) and in field exercises by the Berlin Brigade indicated virtually no problems with low power (one to two watts) VHF transceivers.

The first series of tests by USAHEL was reported in a USAHEL technical memorandum (6) for operations in a small built-up area; Havre de Grace, Maryland. These tests indicated no problems with street-to-street communications, but the area was small with very few large buildings. The Havre de Grace tests did indicate a problem in communicating from basements and some apparent dead zone anomalies in limited instances.

This report covers a series of communication tests conducted in Philadelphia during 1978 and 1979. Since the tests were conducted in the central high-rise area of Philadelphia as well as in the adjacent two to three-story peripheral area, it is felt that the performances obtained in Philadelphia should be representative of almost any city area, or more precisely stated, the results of the tests should not indicate better performance than would be expected in any other city.

The purpose of the USAHEL tests was to obtain communication performance estimates for scenarios related to typical communications networks used by small tactical units in MOBA.

GENERAL CONDUCT OF THE TESTS

There were three general types of tests conducted within the overall test scope:

Street-to-Street

Building-to-Building

Building-to-Street

Each of these classifications indicate the type of test as described by its title; i.e., in street-to-street tests one operator in the street attempted to communicate with another operator in the street, etc.

Irrespective of the type of test, the criterion for a successful communication attempt was based upon a quality rating system for voice communication. The operator receiving the message, a four digit random number repeated three times, graded the quality of the message as follows:

Quality 5 - completely clear - no background noise.

Quality 4 - clear message, but some background noise.

Quality 3 - message received correctly, but heavy background noise.

Quality 2 - message incorrectly received or not completely distinguished in heavy background noise.

Quality 1 - squelch break occurred, but no discernible message.

Quality 0 - no squelch break.

A successful transmission was considered to be a quality level of three or higher. In those instances where the operator called a quality of three or higher but the four-digit message was incorrectly received, the quality of the message, as recorded, was downgraded to quality level two.

These quality levels are, in essence, levels of signal-to-noise ratio as judged by the test subjects. Since the objective of these communications trials was to provide an estimate of the conditions under which communication could be affected, no effort was made to investigate communications using the more detailed intelligibility testing procedure.

In all tests conducted by USAHEL, the equipment was operated in the "squelch" mode.

The Philadelphia tests were conducted at two different times. The first series was run in October 1978 and the second series in November 1979. Whenever replications occurred in tests for the two different periods, the results were combined and no separate analysis is given for each period.

The scope of the Philadelphia tests is given in Table 1 below and includes both series of tests.

TABLE 1

Total Attempts to Communicate

<u>Test Type</u>	<u>With PRC-77</u>	<u>With PRC-68</u>	<u>With PRT-4's & PRR-9's</u>
Street-to-Street North-South Grid	978	360	360
Street-to-Street East-West Grid	612	372	372
Building-to- Building	504	210	210
Building-to- Street	396	44	-

EQUIPMENT AND SUBJECTS

The same four AN/PRC-77 sets (Figure 1) were used throughout both Philadelphia series and in other tests which will be discussed below. These four sets were obtained from the US Army Ordnance and Chemical Center and School at Aberdeen Proving Ground, Maryland (APG, MD), on loan. There was some concern initially with the performance of these sets and the cooperation of the Maryland National Guard unit at Havre de Grace, Maryland, was solicited to perform diagnostic tests. The National Guard personnel recommended component replacements in two of the sets and these sets were forwarded to Fort Meade, Maryland, for the recommended repair. After the return of the sets from Fort Meade, there was no further maintenance performed on any of the sets. However, all sets were monitored at intervals to determine the receiver sensitivity and power output and there were no known instances of sets operating below specified levels.

The AN/PRC-68 transceivers (Figure 2) were used as received and functioning was ascertained by simply verifying that communication could be achieved at short ranges.

The squad radios (AN/PRT-4 transmitters and AN/PRR-9 receivers) were fitted with crystal sets which provided an operating frequency of 49.8 MHz. These sets were checked for frequency drift at least once each day during the days that the sets were being tested.



FIGURE 1. A. R. C. 1961



Figure 2. AN/PRC-68 Radio.

In the results reported for the PRC-77 and PRC-68, the 3-foot whip antenna was used on all equipment. The stub antenna issued for the old squad radios was the antenna used in the trials with these sets. In all cases the radios were carried by the operating personnel when the equipment was being tested. When the term "mobile operator" is used in the report, it refers to an operator who would change his position during a test series as compared to a fixed position.

All communication equipment which was considered equipment under test was operated by Army personnel from APG, MD. All personnel had previously operated PRC-77 equipment although none were radio operators per se.

All USAHEL communications tests were controlled by an ^{RT}~~SCR~~-524 set mounted in an Army van located at street level in the vicinity of the tests being conducted. The test controller and data recorder were located in the van (Figure 3) and the sequencing of the communications traffic was performed by the controller who indicated which position was to send the traffic and then queried the individual operator receiving the traffic to determine the quality and content of the message. In those instances where the operator called a quality of three or higher but the four-digit message was incorrect, the quality of the message, as recorded, was downgraded to quality level two.

In all communication tests conducted by USAHEL with the PRC-77 transceivers, the frequency of transmission was either near 30, 50, or 70 MHz. In the discussions below these frequencies are referred to as low, mid or high band, respectively. All tests with the PRC-68 and the squad radios were conducted at mid band.

TEST RESULTS--STREET-TO-STREET TESTS

Figure 4 shows the basic north-south and east-west test grids in the street-to-street tests. Actually, the street-to-street tests represented three levels of severity in a communications environment. The Broad Street leg which involved communications between an operator stationed at City Hall and an operator moving south on Broad Street represented the most favorable environment. On the Broad Street leg, there was no masking of line-of-sight by buildings (Case B). The next most severe communications environment was the cross-town leg of the north-south tests (Case C). In these tests the operator's line-of-sight was always masked by buildings, but the large masking buildings were limited in number. That is, communications were attempted between a position in the high-rise, core-area and a position outside the high-rise area (Figure 5).

The most severe environment occurred with the east-west grid (Case D). In these tests the stationary operator was located at City Hall as before, but operators moved along Chestnut Street and at each communication attempt were positioned approximately 100 feet back from the Chestnut Street intersection. All the east-west tests were conducted in the high-rise, core-area of Philadelphia which stretched from the Schuylkill River to the Delaware River (Figure 6).



Figure 3. Van.

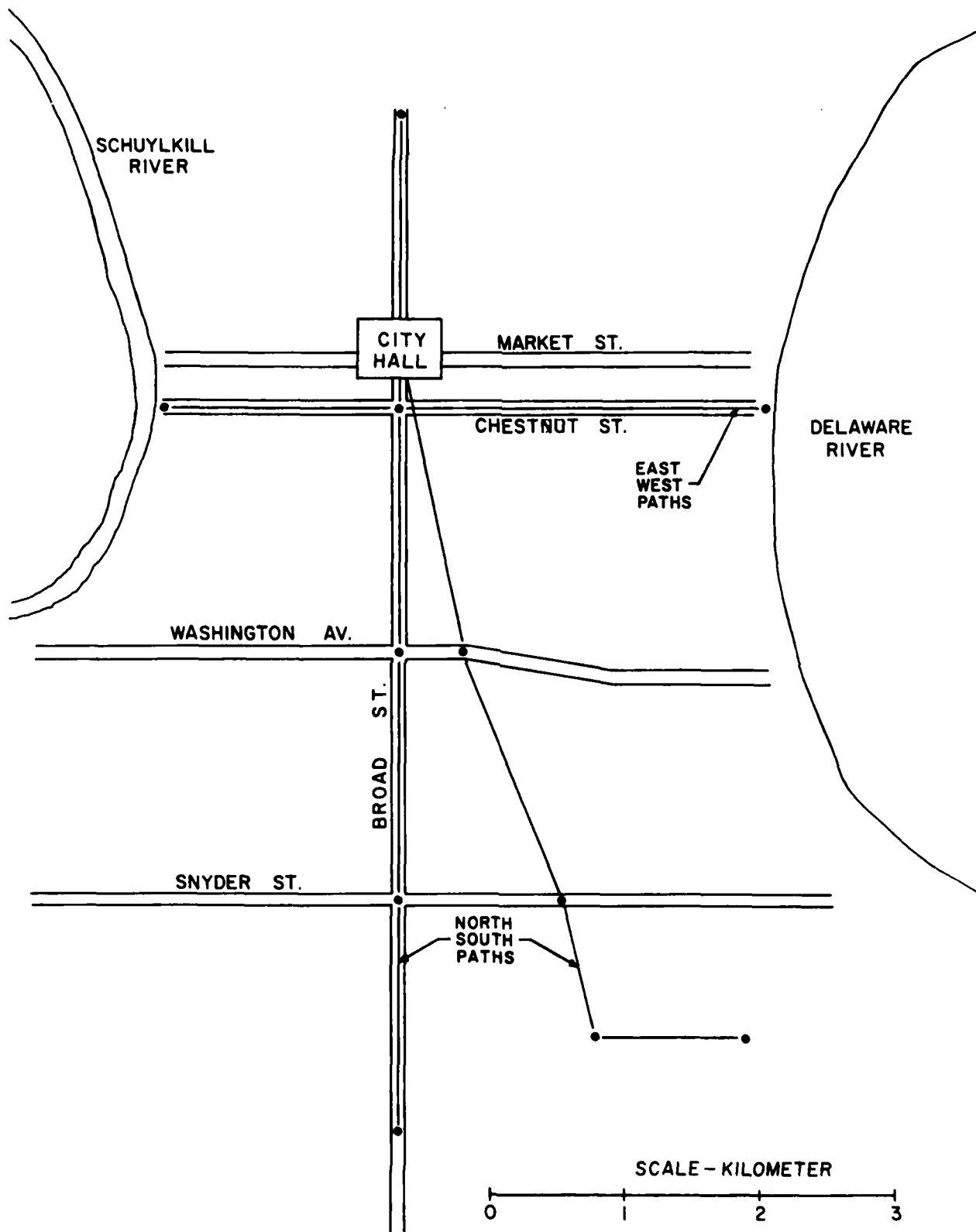


Figure 4. Philadelphia layout map.



Figure 5. A view from the south end of Philadelphia looking north towards the city center. The case "B" and "C" trials were conducted toward this area.



Figure 6. A view of the high-rise core area of Philadelphia looking west from the observation tower at Walnut & 6th Streets.
All Case "D" communications attempts were made in this area.

Figure 7 gives the results of 104 attempts to communicate between City Hall and the Broad Street operator at 30 MHz. The data represent a total of five different tests (two directions each trial) for the first and second Philadelphia test series taken at 11 different positions on Broad Street for each test.

In this particular example and in all the other data reported, a success is a quality "3" or higher as discussed above.

Figure 8 displays the same data for 30 MHz although this time the curve is modified by three-point smoothing and the .9, .8 and .5 probability of success levels are indicated. These three levels of successful communication are used in the basic data comparison of Tables 2 and 3.

A peculiar problem of the data is evident in Figure 8 where probability of successful communication versus range is presented for the 30 MHz trials. The attempted communications were limited to 4.5 km range, and apparently this range was not sufficient to have the success ratio approach zero. Although the sampling rate was much lower (per kilometer) at the longer range, it does appear that there is some tendency for communications to improve at the longer ranges. Since the probability levels do not ever return to the .9 value, it was felt that the relatively high P values at long range should be discounted for the present until propagation phenomenon are better understood. Or an alternative way of stating the problem is; based on this data we do not want to give the impression that troops operating in a city can improve their communication performance by increasing the range between stations even though this may, on occasion, be true. It is doubtful that radio communications will ever be improved to a much higher level of reliability by having one operator increase his range from the station with which communications are being attempted.

The communication performance ranges in Tables 2 and 3 for the .9, .8 and .5 probability of success levels are based upon three-point smoothing of the basic data as noted above. Many of the probability versus range functions for Cases B, C and D do not approach zero at the longest test ranges. In fact, a number of these relations do not even get down to the .5 level. Others go below the .5 level but exceed the .5 level at the longest ranges. The range reported in the tables is the shortest range at which the smoothed relation intercepts the indicated probability level. Hence, especially for .5 values, the indicated ranges are under estimates of the performance of the transceivers.

Every effort has been made to avoid propagation "explanations" in this report. However, in this one case it is conjectured that the diffraction of electromagnetic waves around or over buildings may be responsible for modest increases in probability levels at increased ranges. That is, for a fixed location surrounded by large buildings and communicating with a mobile position moving away from the large buildings, the decrease in the one diffraction angle may more than compensate for the losses due to increase in range.

SUCCESS RATIO AS A FUNCTION OF RANGE

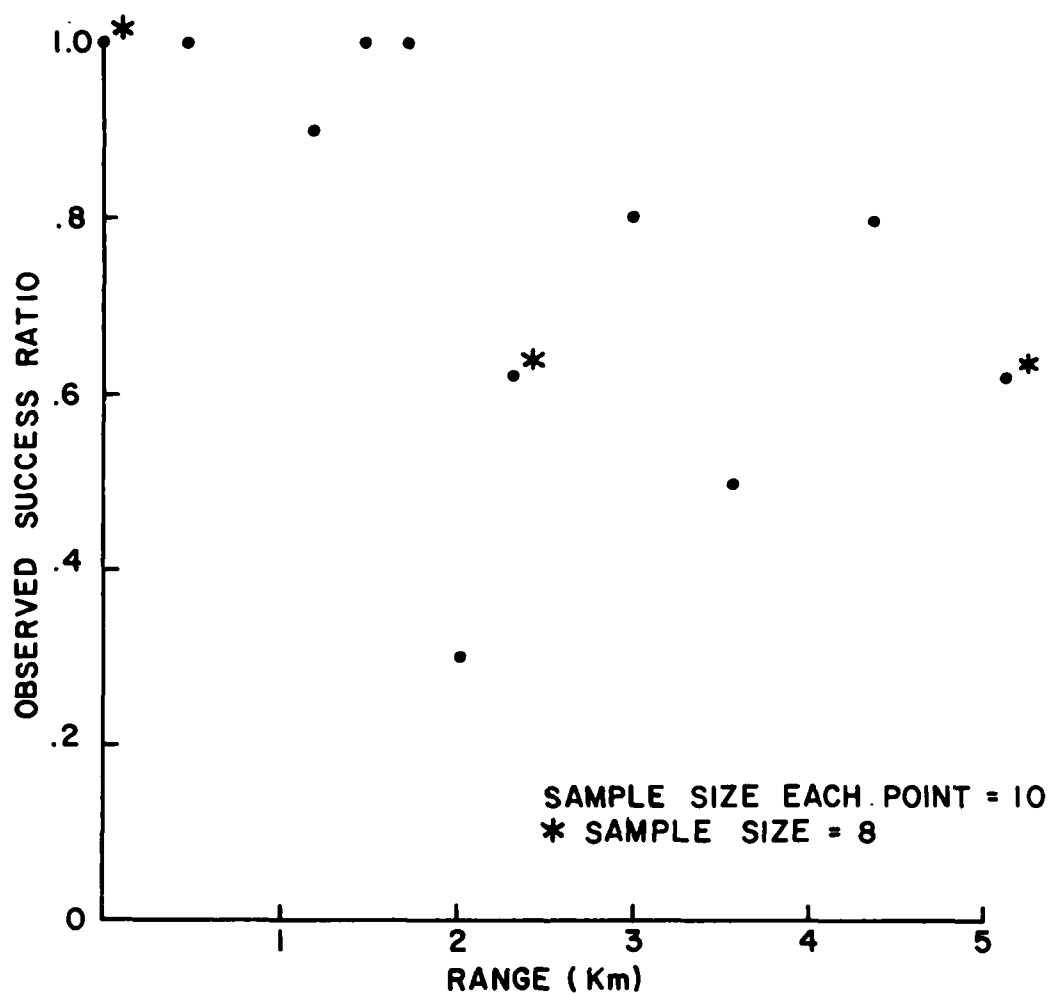


Figure 7. Example of the basic data from communications trials, PRC-77, 30 MHz, Case "B", street-to-street.

PREDICTED PERFORMANCE VS RANGE

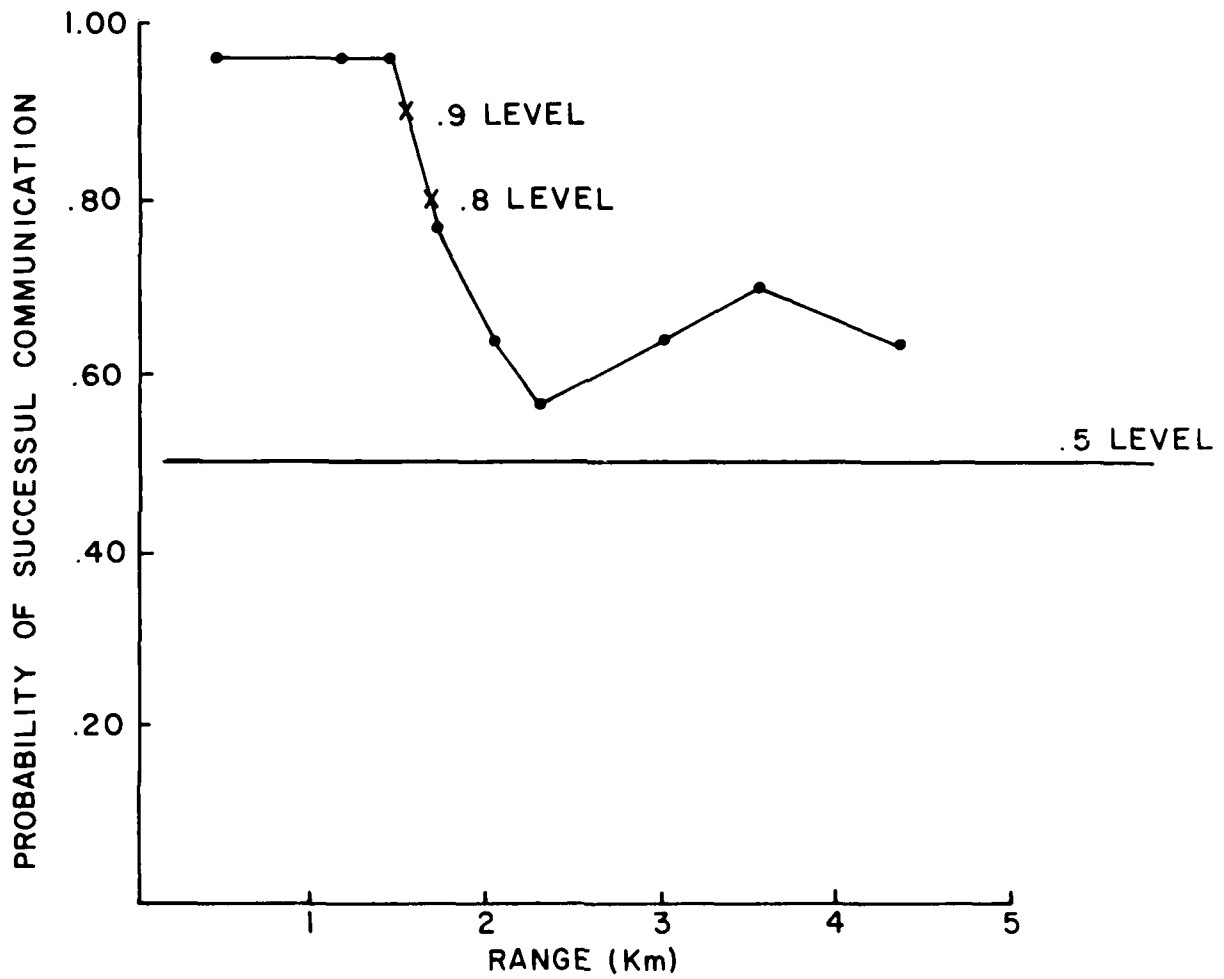


Figure 8. Example of the smoothed data from communications trials, PRC-77, 30 MHz, Case "B", street-to-street.

TABLE 2

Communications Performance of the PRC-77 in Street-to-Street Operations
(Entries are ranges, in km, at which indicated probabilities are achieved)

<u>30 MHz</u>				
<u>Case</u>	<u>Probability of Communication</u>			<u>N</u> <u>(Sample Size)</u>
	<u>.90</u>	<u>.80</u>	<u>.50</u>	
A	3.98	4.09	6.12	108
B	1.64	1.67	> 4.34*	104
C	< .50*	1.27	2.03	104
D	.88	1.21	1.58	204
<u>50 MHz</u>				
<u>Case</u>	<u>Probability of Communication</u>			<u>N</u> <u>(Sample Size)</u>
	<u>.90</u>	<u>.80</u>	<u>.50</u>	
A	3.17	3.34	6.12	108
B	2.77	3.38	> 4.34	108
C	1.53	2.80	> 4.04	108
D	1.24	1.43	1.84	204
<u>70 MHz</u>				
<u>Case</u>	<u>Probability of Communication</u>			<u>N</u> <u>(Sample Size)</u>
	<u>.90</u>	<u>.80</u>	<u>.50</u>	
A	1.84	3.60	4.20	88
B	2.30	3.29	> 4.34	108
C	1.19	3.95	> 4.04	108
D	.82	1.47	1.77	204

*In the tables the entry ">4.34" indicates the performance range was greater than 4.34 km. With three-point smoothing of the data, this means the next largest range was 4.34 km. Similarly for the notation. <.50, the next smallest range was .5 km and the average probability of communication was less than that indicated at the top of the column.

TABLE 3

Street-to-Street Results
(Ranges in km. at Which the Indicated Probabilities of Communication
Were Achieved with PRC-68, AN/PRT-4, AN/PRR-9)

Case	PRC-68 (in km.)			N (Sample Size)
	Probability of Communication .90	.80	.50	
A	1.58	1.74	2.72	30
B	.46	1.25	1.70	60
C	.50	.50	1.33	60
D	.22	.41	.45	150
AN/PRT-4, AN/PRR-9				
B	.46	.46	.60	60
C	.50	.50	.50	60
D	.07	.07	.11	156

Also included with this data for street-to-street performance (Tables 2 and 3) is a "Case A" which is the compilation of a series of tests in the open terrain of Maryland's flat Eastern Shore (Figures 9 and 10). The Eastern Shore tests were conducted at four different times with the same four PRC-77 sets as those used in the Philadelphia tests. The four Eastern Shore tests were conducted before, between, and after the two Philadelphia tests. The "open" tests were conducted in approximately the same manner as the Philadelphia tests with one stationary position (at Lynch in Kent County, Maryland) and one or more mobile stations attempting to communicate with each other and the stationary unit. Four different paths were traversed in the Eastern Shore trials; essentially north, south, east and west out of Lynch, Maryland.

The results of Table 2 (PRC-77) indicate that there is a fairly substantial reduction in communication range performance for operations in built-up areas when compared to performance in flat, open terrain. However, the extent of the reduction in performance is certainly frequency dependent for Cases B and C. At the low band (approximately 30 MHz) the range reduction is better than 50% (except for the .5 probability level in Case B). However, at the 70 MHz level there is virtually no reduction compared to the open area performance but it is also apparent that open area performance is also frequency dependent and the high frequency performance is not as good as that at the mid and low band frequency.



Figure 9. Aerial view of the control van located at Lynch, Maryland for the eastern shore trials.

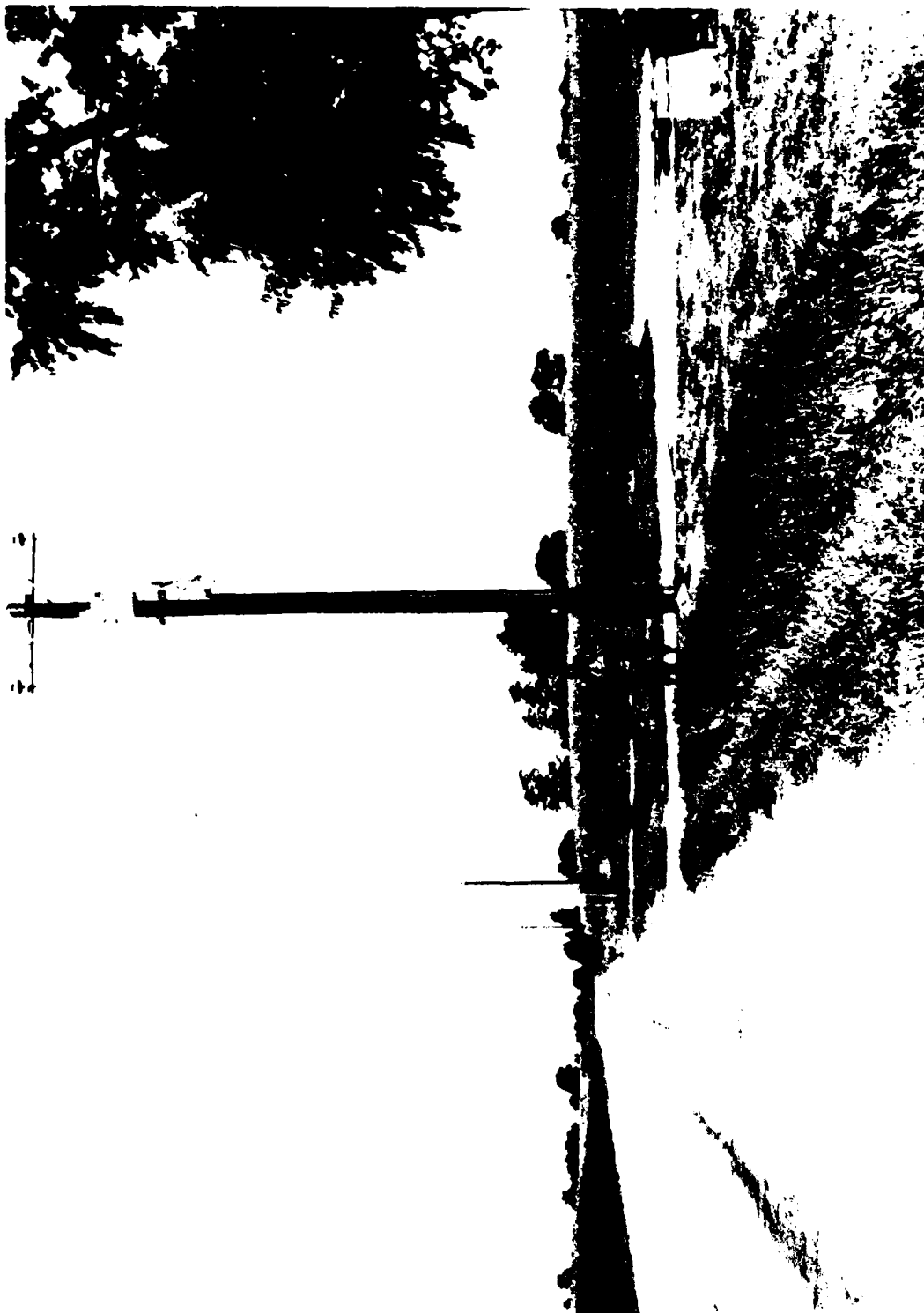


Figure 10. A communications post in the Eastern Shore, Maryland trials,
Case "A".

The PRC-68 and the old squad radio (PRT-4 transmitter and PRR-9 receiver) were included in the second series of Philadelphia tests. In addition, some very limited tests with the PRC-68 were conducted on the Eastern Shore, Maryland grid. The results of these tests are given in Table 3. Cases A, B, C and D represent increasing severity of environment (increasing size and number of buildings) as discussed above and as used in Table 2. It is apparent that the PRC-68 is adequate for operations between units located within several blocks of each other in the high-rise area. Furthermore, it could be used at distances up to 1 kilometer if there is no building masking. It is also quite clear that the old squad radio operating at its normal output of one-half watt power would have virtually no value in built-up areas.

Although operations with the PRC-77 and PRC-68 transceivers in MOBA degrade range performance when compared to the performance in open terrain, the required operating ranges for MOBA are also reduced.

Field Manual (FM) 90-10 (1) in discussing the attack frontages in an urban area states, "...a company team will seldom be assigned a zone greater than one to two blocks in width..." A graphical display in the same document gives company attack frontages varying from 150-200 meters in the densest built-up area to 400-600 meters in the relatively open outlying areas. A similar graph in the same document indicates that defensive sectors would be roughly double the width of the attack sectors.

Figure 11 illustrates the change in maximum offensive and defensive sector widths as a function of complexity of built-up areas (Pages 2-15 and 3-17 of FM 90-10). Also included in the same figure is the performance of PRC-77 and PRC-68 radios as a function of the severity of the communications environment. Although the two classifications, i.e., complexity of built-up area and severity of communications environments do not precisely correspond, the two are closely related. Thus, the figure attempts to display both the performance requirements (sector width) and the measured performance (from the repeated tests) of the two communication systems for street-to-street operations.

We would conclude from this figure that the PRC-77 is adequate for netting Battalion units for defensive operations. (However, CP to CP communications in the defense present another problem discussed in the building-to-building tests below!) The PRC-68, however, would be limited to company/team level operations in the less demanding offensive role, but as a squad radio, the PRC-68 should be capable of operating with the required range for the platoon, even in the defense. The performance of the old squad radio, not included in Figure 9, would not be adequate for MOBA operations.

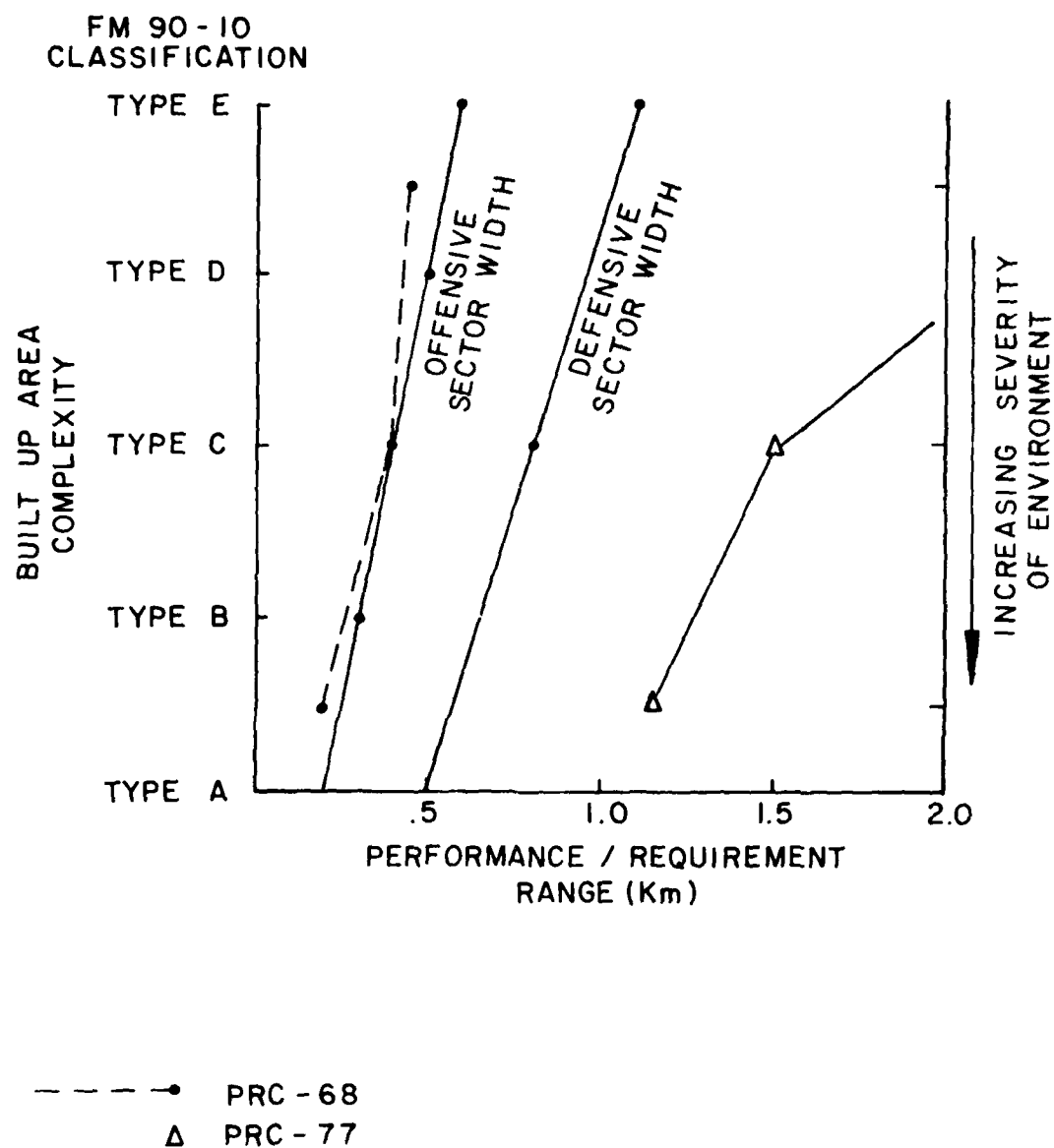


Figure 11. A comparison of company/team sector widths and radio performance range (P level, 50 MHz).

DISCUSSION OF RESULTS--BUILDING-TO-BUILDING TESTS

Figure 12 shows the location of the various sites from which communications were attempted in the building-to-building tests. Three different buildings were utilized in these tests. The oldest structure used was the City Hall (Figure 13) located at the intersection of Broad and Market Streets. The building is of brick-mass construction. The other enclosed building was the Medical Building (Figure 14) at 8th and Race Streets. This is a relatively modern building of steel frame construction with light cladding for outer walls. The third structure was a parking garage (Figure 15) with open side walls and reinforced concrete supporting piers and floors. The fourth location in these tests was a "man-on-the-street" located at Cherry and 10th Streets.

Unlike the street-to-street communications tests where the same patterns were repeated in Philadelphia I & II tests, the building-to-building test designs were changed for Philadelphia II.

The test protocol in the building-to-building tests involved four different positions in the Philadelphia I tests and seven different position in the Philadelphia II tests.

That is, at the start of each sub-test in the building-to-building tests, each operator would proceed to position 1 and all communications attempts would be made between operators. Once the communications traffic was concluded at position 1, all operators would then move to position 2 etc. Throughout each sub-test, the operator on the street would remain at the same position as indicated in Figure 12.

The conditions for the positions are given in Table 4.

The two positional parameters varied in the building-to-building tests were floor height and side of building. That is, for a given floor the operator was placed either "near" to the other building or "far" from the other building.

In Tables 5 and 6 showing the Philadelphia I and Philadelphia II results, it is fairly apparent that communications between positions inside buildings could be established if the operators were located high enough inside the buildings.

Out of 288 attempts to receive messages in Philadelphia I, there were only 27 failures. Seventeen of these failures occurred in position 4, and 7 out of the remaining 10 were failures in receiving City Hall by the operator in the street.

However, it was not clear whether the failures to communicate at position 4 were due primarily to the operator's location being at the lower levels or whether it resulted from being located at the far sides of the buildings.

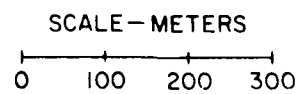
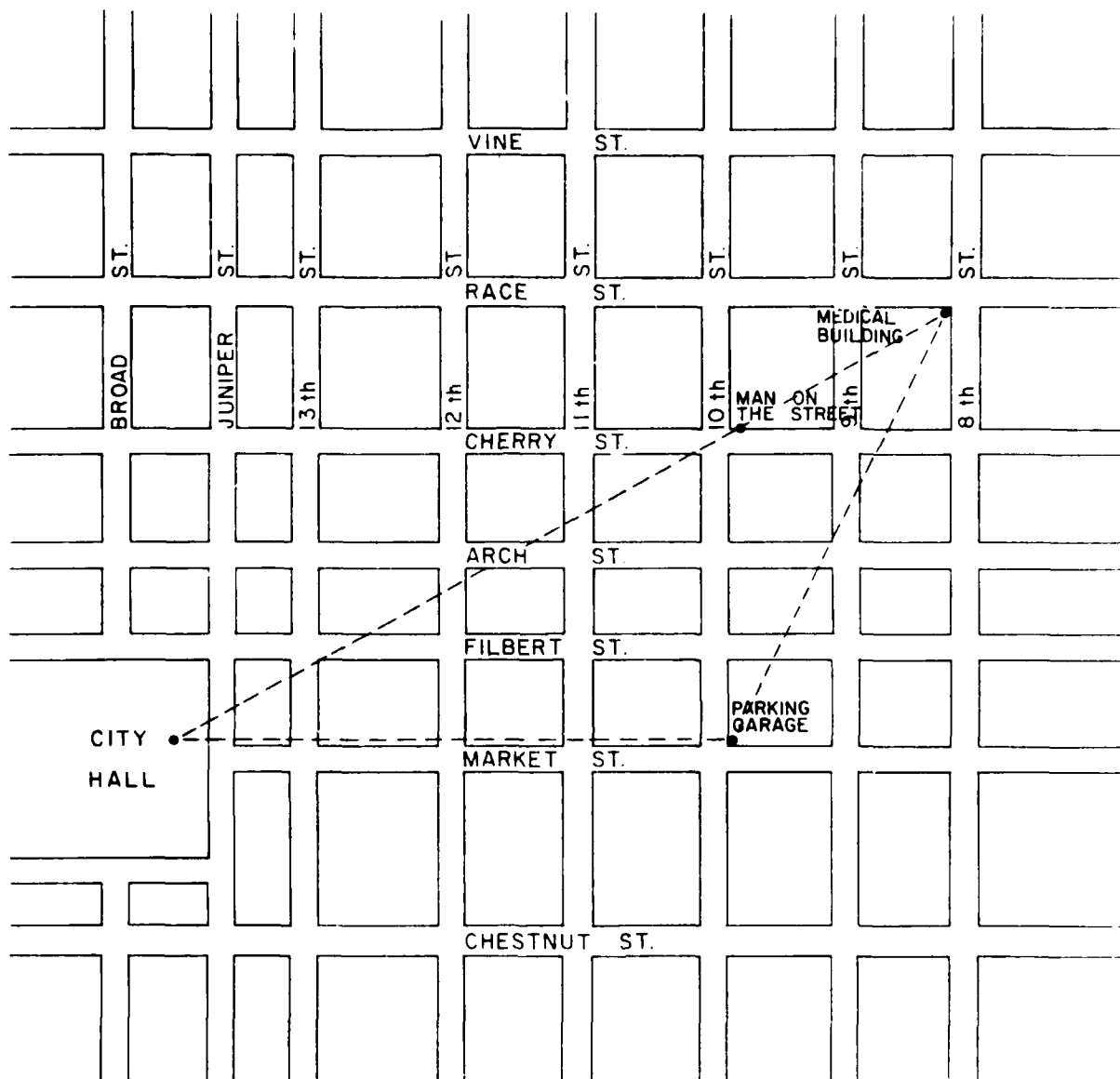


Figure 10. The "Loop" map.



Figure 13. City Hall.

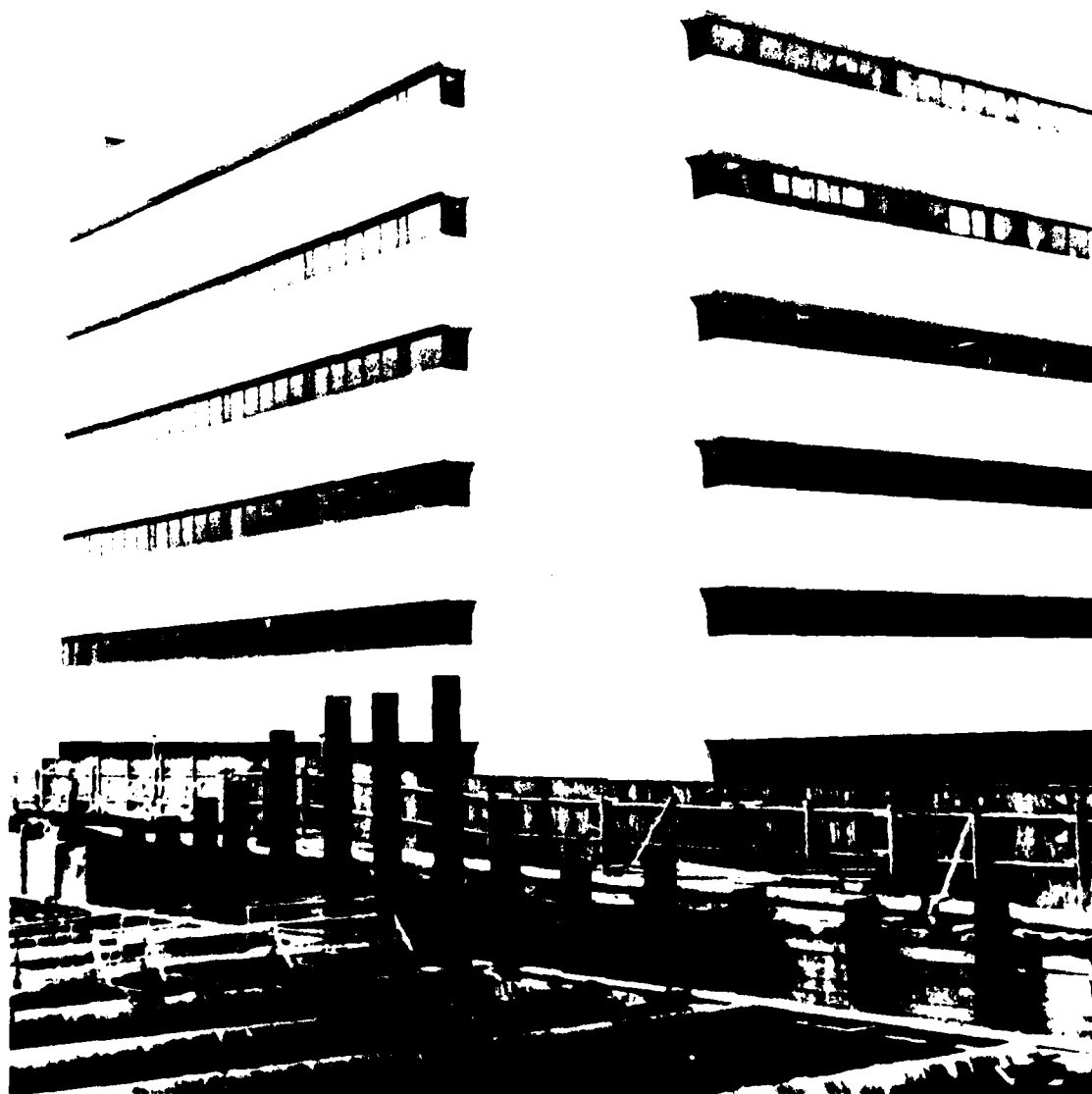


Figure 14. Medical Building.

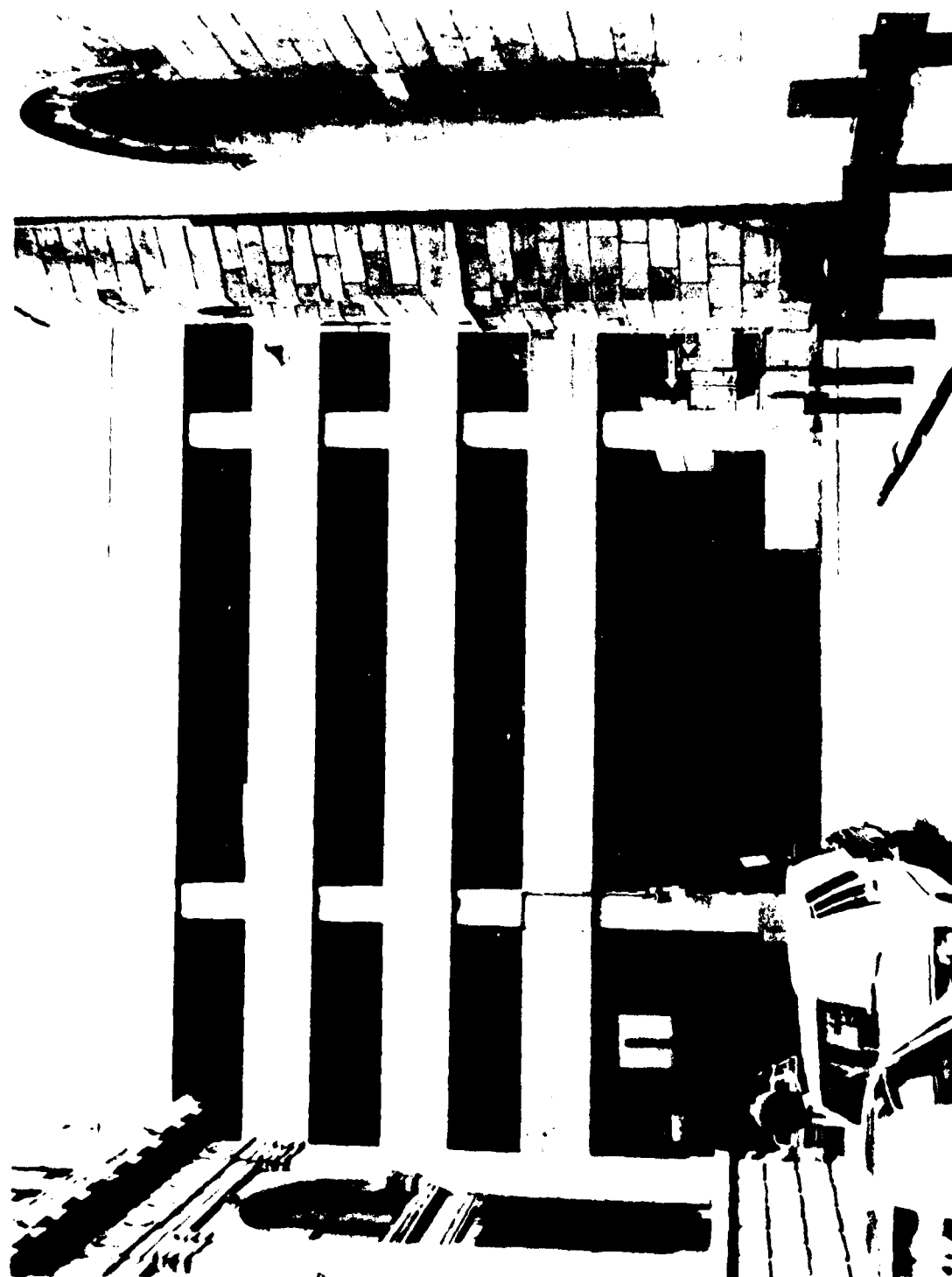


Figure 15. Parking garage.

TABLE 4

Positions in Buildings for the
Philadelphia Building-to-Building Tests

Philadelphia I

	City Hall		Parking Garage		Medical Building	
	Side	Floor	Side	Floor	Side	Floor
Position 1	near	6	near	3	near	6
Position 2	near	3	near	2	near	3
Position 3	near	1	near	1	far	3
Position 4	far	4	far	1	far	1

Philadelphia II

	City Hall		Parking Garage		Medical Building	
	Side	Floor	Side	Floor	Side	Floor
Position 1	near	4	near	2	near	1
Position 2	near	1	near	4	near	1
Position 3	near	1	near	2	near	4
Position 4	far	1	far	2	far	4
Position 5	far	1	far	4	far	1
Position 6	far	4	far	2	far	1
Position 7	near	4	near	4	near	4

TABLE 5

Building-to-Building Tests, PRC-77
 (Successes out of 4 attempts to communicate - Philadelphia I)
 (Successes out of 2 attempts to communicate - Philadelphia II)

Philadelphia I

Freq., MHz	City Hall to Parking Garage				City Hall to Medical Building				Parking Garage to Medical Building			
	30	50	70	TTL	30	50	70	TTL	30	50	70	TTL
Position 1	4	4	4	12	4	4	4	12	4	4	4	12
Position 2	4	4	4	12	3	4	4	11	4	4	4	12
Position 3	4	4	4	12	2	4	4	10	4	4	4	12
Position 4	4	4	1	9	2	4	2	8	1	2	0	3

Philadelphia II

Freq., MHz	City Hall to Parking Garage				City Hall to Medical Building				Parking Garage to Medical Building			
	30	50	70	TTL	30	50	70	TTL	30	50	70	TTL
Position 1	2	2	2	6	0	0	0	0	2	2	2	6
Position 2	2	2	1	5	0	0	0	0	2	2	2	6
Position 3	2	2	2	6	0	2	2	4	2	2	2	6
Position 4	0	2	1	3	0	1	0	1	2	2	1	5
Position 5	1	2	1	4	0	0	0	0	1	2	2	5
Position 6	1	2	0	2	2	1	2	5	0	0	1	1

TABLE 6

Building-to-Building Tests, PRC-77
(Successes with Street Position, 10th & Cherry)
(see explanation of previous table)

Philadelphia I

Freq., MHz	Street to City Hall				Street to Parking Garage				Street to Medical Building			
	30	50	70	TTL	30	50	70	TTL	30	50	70	TTL
Position 1	4	4	4	12	4	4	4	12	4	4	4	12
Position 2	4	3	3	10	4	4	4	12	4	4	4	12
Position 3	2	3	2	7	4	4	4	12	4	4	4	12
Position 4	4	4	4	12	4	4	3	11	4	4	4	12

Philadelphia II

Freq., MHz	Street to City Hall				Street to Parking Garage				Street to Medical Building			
	30	50	70	TTL	30	50	70	TTL	30	50	70	TTL
Position 1	2	2	2	6	2	2	2	6	2	2	2	6
Position 2	2	2	2	6	2	2	2	6	2	2	2	6
Position 3	2	2	2	6	2	2	2	6	2	2	2	6
Position 4	2	2	2	6	2	2	2	6	1	2	2	5
Position 5	2	2	2	6	2	2	2	6	2	2	2	6
Position 6	2	2	2	6	2	2	2	6	2	2	2	6

An attempt was made to understand the impact of near versus far locations in buildings in the second set of Philadelphia tests and the tests were planned to isolate this variable. In addition, there was some reconsideration of the test plan based upon tactical use of radios. While it is important to recognize that communication between two operators located high in buildings (both four to six stories) was extremely successful, tactically this is a very low frequency occurrence. Hence, in the second set of tests there was one, and only one operator, at the high level for any test situation in the first six positions.

The results for the second Philadelphia tests with the PRC-77 were entirely different from the first tests. Out of 216 attempts to communicate, there were 43 failures. Forty-two of these failures occurred in the 108 trials between buildings with only one failure to receive out of 108 attempts between the street position and the building positions.

If position 4 of the Philadelphia I tests (building-to-building) is compared with the six positions of the Philadelphia II tests, the success ratios are .56 and .61 respectively. Hence, it is concluded that reliable communications between buildings can be expected only if both transceivers are located three to four stories above street level.

The impact of being on the near side versus far side in buildings was not resolved in the second test series and, essentially, the second set of tests provided only a confirmation of the importance of height in MOBA communications.

The performance of the 68's and squad radios in a building-to-building environment was also examined in the second set of Philadelphia tests. There were only occasional successes with the old squad radios, but the PRC-68 performed reasonably well. (See Tables 7 & 8.)

In 126 attempts to communicate between the old squad radios, there were only 20 successes (Table 7). Fourteen of the 19 successes were between the Medical Building and the parking garage with the operator on the fourth floor of the Medical Building.

In the six positions of the building-to-building tests which were the same as those used by the PRC-77, the PRC-68 performed slightly better than the PRC-77 with 72 successes out of 108 as compared to 66 out of 108 for the PRC-77. However, the PRC-77 results were based on equal numbers of trials at 30, 50 & 70 MHz whereas the PRC-68 trials were all conducted at 50 MHz. If only 50 MHz results are compared, then the PRC-77 performed slightly better than the PRC-68 with 26 successes out of 36 attempts.

As a final indication of the importance of building height, a seventh position was introduced with all PRC-68 radios on the fourth floor of all buildings, and there were 18 successes out of 18 attempts.

TABLE 7

Building-to-Building Tests
(Successes out of 6 Attempts to Communicate)
50 MHz Frequency Only

PRC-68			
	<u>City Hall to Parking Garage</u>	<u>City Hall to Medical Building</u>	<u>Parking Garage to Medical Building</u>
Position 1	4	0	2
Position 2	6	0	6
Position 3	2	5	6
Position 4	3	5	6
Position 5	6	1	5
Position 6	5	6	5
Position 7	6	6	6
PRT-4 and PRR-9 (Old Squad Radio)			
	<u>City Hall to Parking Garage</u>	<u>City Hall to Medical Building</u>	<u>Parking Garage to Medical Building</u>
Position 1	0	0	0
Position 2	0	0	0
Position 3	0	2	6
Position 4	0	0	3
Position 5	0	0	2
Position 6	0	0	1
Position 7	0	1	5

TABLE 8

Building-to-Building Tests
 Successes with Street Position at 10th & Cherry
 (Successes out of 4 Attempts to Communicate)

	<u>Street-to City Hall</u>	<u>Street-to Parking Garage</u>	<u>Street-to Medical Building</u>
Position 1	4	4	3
Position 2	2	4	2
Position 3	2	3	4
Position 4	3	4	4
Position 5	3	3	3
Position 6	4	4	4
Position 7	4	4	4

PRT-4 and PRR-9 (Old Squad Radio)

	<u>Street-to City Hall</u>	<u>Street-to Parking Garage</u>	<u>Street-to Medical Building</u>
Position 1	0	0	0
Position 2	0	0	0
Position 3	0	0	2
Position 4	0	0	3
Position 5	0	1	0
Position 6	0	1	0
Position 7	0	1	3

DISCUSSION OF RESULTS---BUILDING-TO-STREET TESTS

The results of the building-to-street tests are given in Table 9. The building-to-street tests incorporated one leg of the north-south grid (cross town) with two buildings of the building-to-building tests. More specifically, there were two radio operators, each with a PRC-77 set, located on the second floor of City Hall. There were two operators located in the Medical Building on the third floor: one operator had a PRC-77 set and the other had a PRC-68 set. A team of two operators moved south on the cross-town leg and, similar to the arrangement at the Medical Building, one operator carried a PRC-77 set and the other a PRC-68 set.

Although the two operators in City Hall each had PRC-77 sets, different antennas were used. One set had the standard 3' whip antenna while the other set had a special cable antenna attached which was draped outside the window. This is the only configuration where the operator was located inside a building and anything protruded outside the building. There was no discernable difference in the performance of the two antennas and the results of the PRC-77 sets in City Hall were combined for Table 9.

If the results of Table 9 are compared with Tables 2 & 3, some improvement is noted in performance over the street-to-street case C for those communications associated with the Medical Building where the operators were located on the third floor.

However, the performance for City Hall (operations on the second floor) was about the same as the street-to-street performance.

Essentially, this test represents a sample size of one for a three-story location and one for a two-story location and it is probably incorrect to draw conclusions that improvement in communication occurs when moving from the second to the third floor. However, these results are consistent with the building-to-building tests which show that floor height is important and that the disadvantage of being inside a building can be countered by locations at upper floors in a building.

TABLE 9

Building-to-Street Test Results
 (Entires are ranges, in km, at which indicated probabilities are achieved)

<u>PRC-77</u> <u>FREQ. 30 MHz</u>				
	Probability of Communication			N (Sample Size)
	<u>.9</u>	<u>.8</u>	<u>.5</u>	
Case C, Street-to-Street (From TABLE 2)	<.50	1.27	2.03	104
Street-to-3rd Floor Medical Building	1.56	2.02	2.47	44
Street-to-2nd Floor City Hall	1.79	1.84	4.20	88
<u>50 MHz</u>				
	Probability of Communication			N (Sample Size)
	<u>.9</u>	<u>.8</u>	<u>.5</u>	
Case C, Street-to-Street	1.53	2.80	> 4.04	108
Street-to-3rd Floor Medical Building	2.81	3.67	4.46	44
Street-to-2nd Floor City Hall	1.79	1.84	4.20	88
<u>70 MHz</u>				
	Probability of Communication			N (Sample Size)
	<u>.9</u>	<u>.8</u>	<u>.5</u>	
Case C, Street-to-Street	1.9	3.95	4.04	108
Street-to-Medical Building	2.68	2.98	3.77	44
Street-to-City Hall	.65	3.40	4.20	88
<u>PRC-68, 50 MHz</u>				
	Probability of Communication			N (Sample Size)
	<u>.9</u>	<u>.8</u>	<u>.5</u>	
Case C, Street-to-Street (From TABLE 3)	<.50	<.50	1.33	60
Street-to-Medical Building	1.24	1.36	2.10	44

ADDITIONAL COMMENTS

1. After the Philadelphia tests were completed and the data analysis was nearly completed, a report was distributed by Signatron (2) which gave detailed results of a communications test in Boston, Massachusetts, with a PRC-77 radio. These results indicated much poorer performance than that obtained by HEL in Philadelphia. Subsequently, HEL took the same PRC-77 sets used in Philadelphia and with the assistance of Signatron re-ran the Boston trials. This time the Boston results were comparable to the Philadelphia results. Signatron has provided another report (5) on their second Boston tests and attributes the difference in results to "differences in radiated power (i.e. antenna efficiency) of the PRC-77's used in the earlier and the more recent experiment."

Both Boston tests are analyzed by Signatron in terms of measured power losses as a function of range, whereas the HEL reports examine success ratios in voice communication attempts. A separate HEL report on the 1980 Boston test will be provided.

2. The entire series of HEL tests indicates that street-to-street operations can be conducted successfully in built-up areas even though performance is reduced in comparison to open areas. Furthermore, building-to-building communications can be successful without using exposed antennas if both sets are located relatively high (third to fourth floor) in buildings even in areas containing many high-rise buildings.

However, successful MOBA operations with PRC-77 and PRC-68 radios have not been completely demonstrated. If, and when the performance of radio nets can be established in MOBA, where some of the radios in the net are located in basements, then a better statement on the adequacy of present equipment in MOBA can be made. Such tests are planned for the spring of 1981.

Although it is quite clear that basement locations without augmentation (remote antennas, remoting systems or retransmission devices) will severely restrict range performance, recent limited tests by HEL at Aberdeen Proving Ground using basement positions with augmentation showed large improvements over no augmentation.

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